Original Research Article

Determinants of post-harvest losses of pineapple: A farm-level study in Moulvibazar district, Bangladesh

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ABSTRACT

Aims: In most developing countries, post-harvest losses have been identified as one of the major determinants of fresh crops including fruits production. Thus, the present study is highlighted the perishable nature of the food and inefficient post-harvest management are one of the main causes of fruit losses in the Moulvibazar district.

Study Design: This article is about determinants of post-harvest losses study and is placed on empirical analysis. It was conducted to determine the determinants of post-harvest losses of pineapple at the farm level.

Place and Duration of Study: The study was conducted at five regions namely Sreemangal, Barlekha, Kulaura, Juri, and Rajnagar Upazilas were purposively selected as they represent the top five pineapple producing areas of the Moulvibazar district. The study period was the harvesting season of pineapple from April to June 2019.

Methodology: The relevant data were collected using structured questionnaires via face-to-face interviews with 320 pineapple farmers that were selected using simple random sampling. Collected data were analyzed using descriptive, chi-square, and factor analysis.

Results: The descriptive findings revealed that, based on the percentage ranking, all pineapple farmers (100%) were participating in pineapple marketing in search of both direct and indirect ways to sell their produce in order to reduce losses. This means that finding a market for pineapples is essential in order to prevent losses. According to the results of the Chi-square analysis, there was a significant relationship between education level (P=0.049), farm size (P=0.000), farm experience (P=0.021), yield (P=0.000), and post-harvest losses. Furthermore, the results of the factor analysis identified seven factors that influenced pineapple post-harvest losses: harvesting, sorting, grading, packaging, storage, transportation, and marketing. Establishing appropriate storage and packaging facilities will reduce pineapple farmers' losses and make it easier for them to market their prod throughout the year. Moreover, sorting and grading pineapple will increase its value, allowing for better marketing.

Conclusion: It has been shown that the transportation system has a substantial impact on pineapple distribution in the study area. Thus, it is logical to say that the transportation infrastructure should be upgraded in order to reduce pineapple production losses.

Keywords: Post-harvest losses, Post-harvest activities, pineapple farmers, Chi-square analysis, Factor analysis, Moulvibazar, Bangladesh.

1. INTRODUCTION

Fruits play an important role in the overall economic performance of Bangladesh. Production of fruits including pineapple is growing progressively in Bangladesh. Pineapple (*Ananas comosus*) is a major commercial fruit crop in the world as well as in Bangladesh. Because of

its great flavor and taste, it is regarded as the "Queen of Fruits" (Baruwa, 2013). After bananas and citrus fruits, pineapple is the world's third most significant tropical fruit (Bartholomew *et al.,* 2003).

Bangladesh has a lot of fertile areas where a wide variety of tropical and subtropical fruits can be grown. The most commonly cultivated fruits in the country's agricultural territory are mango, jackfruit, blackberry, pineapple, banana, litchi, lemon, guava, custard apple, wood apple, elephant apple, golden apple, Indian berry, papaya, tamarind, melon, watermelon, cashew nut, pomegranate, plum, rose apple, Indian olive, and Indian jujube (BBS, 2020). According to the time-series research, pineapple is the fourth most significant fruit in terms of total planting area and production in Bangladesh (Hossain & Abdullah, 2015). Pineapple is becoming a major industrial product in several countries, and demand for pineapple is growing globally. The future of pineapple cultivation in Bangladesh is bright because, despite the fact that the fruit is grown in roughly 90 countries around the world, Bangladeshi pineapples are more juicy and tasty than others. If correctly marketed, these pineapples are guaranteed to bring in a lot of money in the form of exports (Golam, 2014). Pineapple fruits have a high moisture content, sugar content, soluble solid content, ascorbic acid, and crude fiber content. As a result, pineapple can be utilized as a dietary supplement for good personal health (Hemalatha & Anbuselvi, 2013). Pineapple contains a significant quantity of calcium, potassium, vitamin C, carbohydrates, crude fiber, water, and various minerals that are beneficial to digestion and aid in the maintenance of a healthy weight and well-balanced diet. A single pineapple provides more than 130 percent of the daily vitamin needs for humans. Pineapple reduces cough and cold symptoms, protects against cancer, and improves vision, bone health, oral health, blood circulation, and blood pressure control (Hossain *et al.,* 2015).

Pineapple growing thrives in a tropical climate. It is grown virtually everywhere in Bangladesh, particularly in steep and highland areas where there is little water stagnation. It is a very popular fruit that grows more in the rainy season due to its economic and nutritional benefits. Long periods of drought are detrimental to pineapple production. Drought has an impact on the quality, quantity, and size of this fruit. Despite the fact that Bangladesh is not a tropical country, the climate and soils in many regions of the country are ideal for pineapple production. Pineapples abound in Tangail, Rangamati, Chittagong, Bandarban, Dhaka, Mymensingh, Khagrachari, Sylhet, and Moulvibazar (BBS, 2020).

According to Kader *et al.* (2012), around one-third of the food produced in industrialized and developing nations is wasted, amounting to 1.3 billion tons per year. In medium and high-income countries, a lot of food is discarded. According to an FAO estimate, global volumes of lost and discarded food are larger in downstream stages of the food chain in high-income regions. Still, the converse is true in the low-income areas, where more food is lost and wasted in upstream stages (FAO, 2013). Fruit and vegetable post-harvest losses are estimated to be 30-40% in developing countries after leaving the farm gate (Salami *et al.,* 2010; Aujla *et al.,* 2011), and 12 percent in developed countries from production to retail warehouses, with an estimated 20 percent at retail stores and food manufacturing sites (Madrid, 2011). The notable difference between developed and developing countries is that underdeveloped countries lose fresher fruits and vegetable infrastructure than developed countries (Parfitt *et al.,* 2010).

According to a recent study by Mollah *et al.,* (2018), post-harvest losses in food grains are estimated to be 15%, while losses in fruits and vegetables are believed to be 20-25% in Bangladesh. These losses might be as high as 40% for very perishable fruits and vegetables. This indicates that issues causing low productivity must be identified. In Bangladesh, the post-harvest management of horticulture products is still inadequate. Immediate action is required to enhance the current state of post-harvest management to reduce losses while maintaining quality and safety standards. In general, harvesting can occur at a variety of stages of maturity. Crop losses due to damage or heat concentration in the field can be reduced by using containers properly during harvesting and field management (Rolle, 2006).

Pineapple sales are heavily reliant on marketing. Pineapples cannot be saved until they are put away. Agricultural product marketing, unlike industrial product marketing, is not well organized. Because of this fundamental difference, agricultural product marketing requires the development of unique systems, institutions, and infrastructure. Yeshiwas & Tadele (2021) found that in North-Western Ethiopia the average post-harvest losses of fruits and vegetables were estimated to be 5 to 83% of the market share. Rotting, mechanical damage, poor handling, inappropriate temperature, relative humidity management, and hygiene issues during handling are the most common causes of post-harvest losses.

In Bangladesh, particularly in the Moulvibazar district, no empirical study has been conducted yet to identify and determine the latent factors influencing post-harvest losses among pineapple farmers. Given the above backdrop, it is necessary to understand post-harvest loss assessment and marketing practices of fruits in the Moulvibazar district. In this present investigation, we tried to explicitly estimate and determine the latent determinants or factors influencing post-harvest losses among pineapple farmers in Moulvibazar, Bangladesh. The study will help to identify and determine the factors responsible for the losses of pineapple farmers. In turn, this will help to develop proper measures required to reduce such losses and increase the availability of pineapples for domestic consumption and export purposes. Thus, the overall objective was to identify and determine the latent factors influencing post-harvest losses among pineapple farmers in Moulvibazar district, Bangladesh.

2. MATERIAL AND METHODS

2.1 Selection of the study area and sample

The study was conducted in the Moulvibazar district of Bangladesh including five regions namely Sreemangal, Barlekha, Kulaura, Juri, and Rajnagar Upazilas were purposively selected. A registered list of pineapple farmers and villages was obtained from the Department of Agricultural Extension, of Moulvibazar district. Out of 5 Upazilas, 4 villages from each Upazila were taken, and then 320 pineapple farmers were selected from a total of 20 villages based on a simple random sampling technique. Primary data were collected using structured questionnaires via face-to-face interviews with pineapple farmers from April to June 2019.

2.2 Methods of data collection and analysis

Obtained Information and data from questionnaires were coded and analyzed using SPSS software. To estimate and indicate the post-harvest and estimate the key causes for its loss

in the study area, descriptive and inferential statistics were used. On the basis of percentage and ranking, descriptive analysis was performed to determine the socio-demographic profile and post-harvest activities. Inferential statistics such as Chi-square analysis were used to explore the significant association implemented to explore the significant association between the socio-demographic profile and post-harvest losses of pineapple farmers. Also, Factor analysis was applied to identify factors that influence post-harvest losses of pineapples. The factors that influence post-harvest losses were measured using a Likert scale of 1 to 5 (1 representing strongly disagree and 5 representing strongly agree). The constructs about the factors influencing post-harvest losses of pineapple farmers were adopted from previous literature (Amanullah *et al.,* 2020). Data accuracy tests were conducted to determine whether the data obtained were fit to undergo factor analysis or otherwise through the Kaiser-Meyer-Olkin indicator (KMO), Bartlett's Test of Sphericity, and Varimax rotation method.

3. RESULTS AND DISCUSSION

3.1 Socio-economic characteristics of the respondents

The socio-economic characteristics of the respondents who participated in this study were shown in Table 1. The results indicated that there were no female farmers; representing 100% of the pineapple farmers were males in the study areas. It shows that males contribute a whole proportion to pineapple production, and this could be attributed to certain cultural beliefs, such as the inability of a female to participate in cultivation. Forty-five percent (45%) of the respondents were aged between 41-50, followed by 25% in the age range of 31-40 years old, and 24% were in the age between 51-60 years old. Meanwhile, only 5% aged between 20-30 years and the remaining 1% aged above 61 years old. This is an indication of a strong labor force in the agricultural sector in the study area. It is also noticeable that as high as 29% of the respondents had no formal education, where 41% received primary education, 20% of the respondents had attained secondary education, 9% attained higher secondary education and 1% completed bachelor's degrees. The majority of the pineapple farmers (48%) among the 152 respondents reported 16-20 years of farming experience, 88 respondents (28%) reported between 11-15 years of farming experience, 46 respondents (14%) reported between 6-10 years of farming experience, 28 respondents (9%) reported between 1-5 years of experience whereas, the remaining 6 respondents (1%) had more than 21 years of farming experience. 78 pineapple farmers had below 1-acre size farms which is 24%, 206 respondents (65%) had between 1-5 acres size farms and 36 respondents (11%) had above 5 acres of farms. The yield production below 1-acre size farms was below 1000 kg with 94 respondents (29%), 66% respondents had between 10001-20000 kg yield from 1-5 size farms and the minority of pineapple farmers with 16 respondents (5%) produced more than 20001 kg to above yield from above 5 acres of farms.

Table 1. Socio-economic characteristics of the pineapple farmers (n = 320)

Socio-demographic characteristics	Explanation	Frequency	Percent (%)
Gender	Gender of the respondents		
	Male	320	100
	Female	0	0
Age	Age of the respondents (in years)		

	20-30	16	5
	31-40	80	25
	41-50	144	45
	51-60	76	24
	Above 60	4	1
Education	The highest educational level of the respondents		
	Uneducated or no formal education (0)	92	29
	Primary (Grade 1–5)	130	41
	Secondary (Grade 6–10)	64	20
	Higher Secondary (Grade 11-12)	28	9
	Bachelor (13-16) and above	6	1
Experience	Experience of the respondents (in years)		
	1-5	28	9
	6-10	46	14
	11-15	88	28
	16-20	152	48
	21-above	6	1
Farm size	Farm size of the respondents (acres)		
	Below 1	78	24
	1-5	206	65
	Above 5	36	11
Yield	Yield from the farm of the respondents (kg)		
	Below 10000	94	29
	10001-20000	210	66
	20001-above	16	5

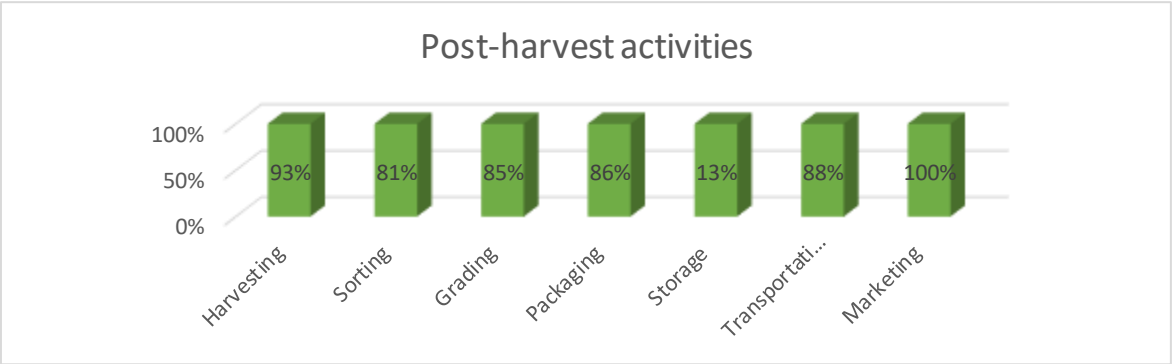
Source: Authors estimation, (2019)

3.2 Identifying of post-harvest activities of pineapple farmers

Harvesting, sorting, grading, packaging, storage, transportation, and marketing are all part of post-harvest handling (Mahmud, 2017). Figure 1 shows the amount of post-harvest activities undertaken by pineapple farmers who participated in this study. Pineapple harvests in the study areas are normally performed by hand-harvesting by pineapple farmers themselves with family members or hired laborers. As the result, 93% of the pineapple farmers in the study areas are harvesting their own pineapples on their own or through labor. 81% of the pineapple farmers in the study areas sort pineapples by their families or by hired laborers. 85% of the pineapple farmers in the study area grade their pineapples based on size, color, and shape. 86% of the pineapple farmers pack their pineapples for the market. In the study area, many pineapple farmers use bamboo-made baskets for packing pineapples and some pineapple farmers use board cartons and crates as well. Only 13% of pineapple farmers keep their pineapples in storage. Eighty-eight percent of pineapple farmers transport their pineapples to the market and finally, 100% of pineapple farmers are involved in the marketing of pineapples. Pineapple farmers sell their pineapples to local, regional traders as

well as retailers and directly to the consumers. This indicates that pineapple farmers use different channels for marketing.

Figure 1. Post-harvest activities of pineapple farmers in Moulvibazar district



Source: Authors estimation, (2019)

3.3 Association between socio-economic characteristics and post-harvest losses of pineapples

The Chi-Square analysis was used to determine the significance of the selected variables in this research. As summarized in Table 2, four variables namely, education level, farming experience, farm size, and yield were found to be significantly associated with the dependent variable. Age, on the other hand, showed a non-significant association with post-harvest losses of pineapples.

Table 2. Chi-square test between socio-demographic profiles and post-harvest losses of pineapples

Variable	χ2	d.f	Sig	Decision
Age	18.302[a]	12	0.221	Failed to reject H_0
Education level	24.407[a]	12	0.049*	Reject H_0
Farm size	129.454[a]	6	0.000**	Reject H_0
Farm experience	27.769[a]	12	0.021*	Reject H_0
Yield	272.539[a]	6	0.000**	Reject H_0

**Significant at 1% level of significance, * Significant at 5% level of significance.
Source: Authors estimation, (2019)

Education level (χ2=24.407, P=0.049) was significant to pineapple post-harvest losses at 0.05% level of significance. This implies that education level has had an effect on the adoption of appropriate agricultural technologies and skills to the farming population over the years. This result is consistent with the findings of Alemayehu *et al.* (2018) and Amanullah et al. (2020), education level has a strong connection with fruit post-harvest losses at (P=0.021) and (P=0.046), respectively, and they concluded that formal education of farmers may lower post-harvest loss when compared to farmers with informal education. Farm size (χ2=129.454, P=0.000) was significant to pineapple post-harvest losses at 0.01% level of significance. This implies that the larger the area put into cultivation, the higher the quantity harvested and chances of losses due to poor handling and lack of proper storage will be reduced. Adisa *et al.* (2015) also indicated in the study of yam post-harvest losses in Nigeria and Amanullah *et al.* (2020) mentioned post-harvest losses of apple in Afghanistan indicate that the larger the area under cultivation, the greater the harvest and the greater the likelihood of losses due to poor management and lack of proper storage.

Farm experience ($\chi 2$=27.769, P=0.021) was significant to pineapple post-harvest losses at 0.05% level of significance. This shows that farmers with more experience have fewer post-harvest losses. This result is also relevant with Alidu *et al.* (2016) and Amanullah *et al.* (2020) that experience has a positive influence on the quantity of fruit loss. Moreover, according to chi-square results, yield also has a significant relationship with post-harvest losses ($\chi 2$=272.539, P=0.000) at a 0.01% significance level. As a result, the lack of suitable storage facilities, an increase in harvested volumes causes damages. This result is also consistent with Alidu *et al.* (2016) and Amanullah *et al.* (2020) that quantity harvested was positively related to quantity loss (P=0.00). However, age status ($\chi 2$=18.302, P=0.221) was not significant to pineapple post-harvest losses. Busari *et al.* (2015) and Amanullah *et al.* (2020) also indicated that there is no significant relationship between the age of the respondent and the quantity of fruit loss (P=0.898) and (P=0.193), respectively. This implies that the age of pineapple producers has no bearing on the post-harvest losses of pineapples in the study areas. This may be presented to the fact of constraints and other production factors can affect post-harvest losses.

3.4 Factors influencing post-harvest losses of pineapple farmers

In this study factor analysis was used to determine factors that influence post-harvest losses of pineapples. The questionnaire contained 31 items linked to factors affecting post-harvest losses, and the validity of the items was investigated using principal components analysis (PCA). The Kaiser-Meyer-Olkin (KMO) measures the sampling adequacy and predicts if the data are likely to be well factored based on correlation and partial correlation ranging from 0 to 1, which should be greater than 0.6 before factor analysis can be carried out (Hair *et al.,* 2009). Table 3 shows that the KMO value was 0.917, indicating inter-correlations between the factors, whereas Bartlett's test of Sphericity was significant (Chi-square=4846.643, P<0.000). Therefore, the data are suitable for PCA (Tabachnick & Fidell, 2014).

As shown in Table 4, seven factors were identified from the 31 items as well as the factor loadings, eigenvalue, and variance. The factors loading of un-eliminated standardized items in this study were in the range of 0.519 to 0.867. If the standardized loading value is more than 0.5, an item is regarded as reliable (Sawyer & Levine, 1966). Therefore, variables with small extraction (below 0.5) were eliminated. Factors with eigenvalues of more than 1 are considered significant whereas those with eigenvalues of less than 1 are considered insignificant and therefore, disregarded. The total variance explained in this study was 66.64%, which is mediocre. This factor solution goes with 33.36% of information lost in the data reduction effort.

Table 3. KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		**0.917**
Bartlett's Test of Sphericity	Approx. Chi-Square	4846.643
	df	465
	Sig.	0.000

Accordingly, harvesting was recognized as the first factor that influences the post-harvest losses of pineapple farmers. This factor consisted of seven sub-variables and had a total variance of 34.733%. The eigenvalue of this factor was 10.42. The result suggests that the harvesting factor is the major consideration concerning post-harvest losses. Utilizing precise harvesting techniques and skilled workers during pineapple harvesting will reduce post-

harvest losses. Fruit harvesting is a crucial stage where fruits are susceptible to bruise damage (Toivoen *et al.,* 2007). If harvested fruits are left on the field for more than four hours after being dispersed on the ground during harvesting, they may become contaminated with spores from the farm. When gasp forces surrounding the fruits approach a threshold for tissue failure, handpicking can cause compression damage (Li & Thomas, 2014). This emphasizes the importance of using proper picking techniques to reduce fruit injuries.

The second factor that influenced post-harvest losses was labeled as sorting, which had a total variance of 9.822% and eigenvalue (4.794) and comprised of four sub-variables. The result indicates that in order to reduce post-harvest losses, pineapple farmers must practice fruit sorting in their fields. Removing non-marketable and defective (reject) fruits, and extraneous materials like stones, boulders, and rubbles, provide an initial quality guarantee to buyers. Pineapple hand sorting involves visual inspection and elimination of undesirable items, and staff needs to be qualified to recognize fruit with incidences of deformities, blemishes or pests, and diseases (Nissen *et al.,* 2016).

The third factor was labeled as grading, which had a total variance of (5.723%) with (2.947) eigenvalue and included four sub-variables. Hence, pineapple grading by size, shape, and color becomes very competitive and immediately sells out on the market and therefore avoids post-harvest losses. Grading is an important part of successful and efficient marketing campaigns that should not be overlooked. Care should be given when grading because untrained labor can injure the skin and allow for microbial contamination (Saeed & Khan, 2010). Grading systems give farmers a wealth of information, including scale, color, shape, defect, and interior condition. Of these, the most significant qualities for the correct categorization and/or sorting of citruses such as oranges, lemons, and tangerines are size and color (Londhe *et al.,* 2013).

Packaging was labeled as the fourth factor, which has a total variance of (4.952%) with (1.717) eigenvalue and consisted of four sub-variables. Packaging is one of the most important factors in reducing post-harvest losses and making vegetables and fruits more appealing to consumers. During transit, distribution, and marketing, standard packaging protects against mechanical intervention, undesirable physiological changes, and pathological degradation (Yahaya & Mardiyya, 2019). A wide range of boxes, such as wooden boxes, bamboo bins, jute sacks, clay pots, and corrugated fiberboard boxes, are important packaging components. Kumar *et al.* (2016) found similar results when assessing losses during long-distance transportation with litchi fruit packaging. Lu *et al.* (2010) discovered that corrugated fiberboard box (CFB) packing is more suitable than typical wooden boxes in avoiding both mechanical and pathological injury to fruits such as apples. Ultimately, innovative packaging technologies may be a key component of initiatives to reduce fruit losses.

The fifth factor was labeled as storage, which has a total variance of (4.713%) with (1.485) eigenvalue and involved four sub-variables. Time management can be improved by storing products, marketing, and consumption can be done more gradually. Storage increases the length of the production season and helps to ensure consistent seasonal fruit distribution. Furthermore, in the value chain, storage is usually required to assure the continuous availability of processing raw materials (Znidarcic & Pozrl, 2006). In a cold storage facility, temperature control is very important. The lowest temperature is ideal for storing fresh fruits

since it does not cause cold damage to the produce (Ramjan & Ansari, 2018). To prevent wastage and maintain the quality of fresh food, appropriate storage capacity, cold storage accessibility, and warehousing facilities are essential (Negi & Anand, 2015).

Table 4. Factor loading of the scale items (scale ranges from 1 (strongly disagree) to 5 (strongly agree)) and Cronbach's alpha coefficient

Code	Scale items	Factor loading
	Factor 1: Harvesting *(reliability (α) = 0.913)*	
Har1	Rough handling at harvest can greatly affect the quality of pineapples	0.913
Har2	Use of skilled workers at harvesting can reduce post-harvest losses of pineapples	0.890
Har3	Poor harvest techniques increase post-harvest losses of pineapples	0.852
Har4	Harvesting of pineapples in non-proper time increase the post-harvest losses	0.846
Har5	Harvesting of pineapples by hand decrease post-harvest losses	0.803
Har6	Harvesting of pineapples by shaking trees increase post-harvest losses	0.784
Har7	Lack of harvesting equipment increase the post-harvest losses of pineapples	0.838
	Eigenvalue	10.42
	Percentage of variance	34.733
	Cumulative percentage of variance	34.733
	Factor 2: Sorting: *(reliability (α) = 0.892)*	
Sort1	Sorting practices decrease the post-harvest losses of pineapples	0.895
Sort2	Sorting to remove low quality will be useful for maintaining the quality of the pineapples and decrease the post-harvest losses	0.847
Sort3	Non-availability of skilled labor in sorting increase apple post-harvest losses	0.861
Sort4	Lack of sorting automatic machine increase the post-harvest losses	0.832
	Eigenvalue	4.794
	Percentage of variance	9.822
	Cumulative percentage of variance	44.555
	Factor 3: Grading*: (reliability (α) = 0.801)*	
Grad1	Grading of pineapples based on size increase the market value and decrease the post-harvest losses	0.846
Grad2	Grading of pineapples apples based on maturity index or color increase the market value and decrease the post-harvest losses	0.835
Grad3	Grading of pineapples based on shape increase the market value and decrease the post-harvest losses	0.763
Grad4	Non-available of grading machine increase the post-harvest losses of pineapples	0.729
	Eigenvalue	2.947
	Percentage of variance	5.723
	Cumulative percentage of variance	50.278
	Factor 4: Packaging*: (reliability (α) = 0.743)*	
Pack1	Non-availability of packing materials increases the post-harvest losses of pineapples	0.841
Pack2	Use of proper packaging prevents pineapples from physical	0.872

	damages	
Pack3	Use of wooden crates decrease the post-harvest losses during transportation	0.738
Pack4	Non-available of packaging machine increase the pineapples post-harvest losses	0.719
	Eigenvalue	1.717
	Percentage of variance	4.952
	Cumulative percentage of variance	55.229
	Factor 5: Storage: *(reliability (α) = 0.871)*	
Stor1	Non – availability of storage facility increases post-harvest losses of pineapples	0.775
Stor2	Keeping harvested pineapples under the shaded area or away from direct sunlight decreases the post-harvest losses	0.838
Stor3	Poor infrastructure of cold storage affects the quality of pineapples and increase the post-harvest losses	0.782
Sort4	Limited space of warehouses increases the post-harvest losses of pineapples	0.734
	Eigenvalue	1.485
	Percentage of variance	4.713
	Cumulative percentage of variance	59.943
	Factor 6: Transportation: *(reliability (α) = 0.891)*	
Trans1	Using different kind vehicles for pineapples transferring increase the amount of losses of apples	0.826
Trans2	Stored pineapples are transferring to market without quality damaged	0.852
Trans3	Pineapples low-level packaging status during transportation affect the quality and increase the losses	0.761
Trans4	Rough loading and unloading of pineapples can greatly increase physical damage to pineapples and increase the losses of pineapples	0.682
Trans5	Without packaging, transferring of pineapples to market increase the losses	0.748
	Eigenvalue	1.414
	Percentage of variance	3.457
	Cumulative percentage of variance	63.399
	Factor 7: Marketing: *(reliability (α) = 0.815)*	
Mark1	Unstable and low market price increase the losses of pineapples	0.856
Mark2	Lack of product specification information increase the losses of pineapples	0.847
Mark3	Lack of reliable market information increases the losses of pineapples	0.744
	Eigenvalue	1.037
	Percentage of variance	3.235
	Cumulative percentage of variance	66.635

Source: Authors estimation, (2019)

Transportation was labeled as the sixth factor with an eigenvalue of 1.414. This factor explained a total variance of 3.457% and consisted of five sub-variables. The most significant areas of post-harvest loss are transportation and distribution of the crops (Ramjan & Ansari, 2018). Pineapple farmers have to transfer their pineapples in different kinds of vehicles for decreasing losses. Only a modern and professional transportation system can tackle the problems of time and distance. Vehicles transporting fresh food must be equipped

with a refrigeration temperature system in order to maintain product quality throughout the travel (Kitinoja & Thompson, 2010). Mechanical damage is usually caused by hard handling or vibration during shipment (Aba *et al.,* 2012). Therefore, quick and modern transportation of fruits is crucial for effective high-quality marketing and conservation.

The last factor that affects the losses was labeled as marketing, with a total variance of (3.235%), (1.037) eigenvalue, and included three sub-variables. Horticultural produce must reach the market as soon as possible and at a period when it is most demanded by consumers. It is indeed essential to have a good marketing system in place to reduce fruit losses and to get a good return on the same products (Ramjan & Ansari, 2018). A great and effective marketing strategy is important to prevent fruit and vegetable losses, and it is possible to get a decent return for the effort and resources invested at a time when the consumer wants the product the most (Yahaya & Mardiyya, 2019). Producers of significant commodities in major production areas should be encouraged to form marketing cooperatives. Because of the small size of farms in developing nations, such organizations are extremely important (Kader, 2004).

After the factor analysis, internal reliability tests were conducted to verify the internal accuracy of the measuring element and Cronbach's alpha of the seven-factor components. The alpha scored in this study ranged between 0.743 to 0.913, which exceeded the minimum requirement guideline by Nunnally (1978) of explanatory research which is above 0.5. Table 4 shows the internal reliability test of the latent factors. Harvesting (0.913) scores the highest reliability value which indicates good internal consistency among the items representing each factor. This was followed by sorting (0.892), transportation (0.891), storage (0.871), marketing (0.851), grading (0.801) and packaging (0.743).

4. SUMMARY AND CONCLUSION

The study has shown that post-harvest losses are very significant in pineapple production in Moulvibazar district, Bangladesh. Findings of the study revealed that numerous pineapple farmers were involved in all post-harvest activities based on various percentage rankings. All (100%) pineapple farmers were engaged in marketing activity to sell their pineapples direct or indirect channels. Therefore, a great and effective marketing strategy is essential to prevent pineapple losses. Furthermore, there was a significant relationship between pineapple farmers' education level, farm experience, farm size, yield, and post-harvest losses. Hence, raising or improving the education level of pineapple farmers, experience and storage will minimize the post-harvest losses. Seven factors were extracted to identify which factors influenced post-harvest losses of pineapples namely harvesting, sorting, grading, packaging, storage, transportation, and marketing. Based on the findings, this study concludes that pineapple farmers need storage facilities and a suitable transport system to reduce the losses. Moreover, sorting, grading, and packaging are the three other most significant and necessary factors that lead to higher market sales and the standard packaging system avoids the pineapple losses encountered by apple growers. Generally, to reduce the existing high post-harvest loss of pineapple and supply quality products for consumers throughout the year, sustainable multi stakeholder's linkage with responsible bodies is required. The findings of this study can assist the government with the right policy and agriculture development of pineapple production in Bangladesh that will benefit the stakeholders in the industry. For the future, the current study suggests the following intervention areas. To ensure that consumers receive high-quality produce, a permanent

selling shade/area for fruits and vegetables should be constructed. Moreover, simple evaporative cooling storage solutions such as zero energy or cooling chambers can be used to maintain quality and increase the shelf life of perishable horticulture crops. Thus, farmers, traders, and consumers need to be trained on novel post-harvest handling procedures of fresh fruits and vegetables right away. In addition, infrastructure for fruit and vegetable crops should be created, such as storage, transportation networks, and packaging. At the same time, the government and other officials should establish clear guidelines and standards for fruit and vegetable retailers' certification.

ETHICAL APPROVAL

This article is original and contains unpublished materials. The corresponding author confirms that all of the authors have read and approved the manuscript and no ethical issues are involved.

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ACRONYMS, ABBREVIATIONS

BBS: Bangladesh Bureau of Statistics
et al.: Et alia (L.) and others
Etc. : Etcetera
i.e. : That is
SPSS: Statistical Package for the Social Sciences
% : Percentage